STATUS AND FUTURE EVOLUTION OF GAAS TECHNOLOGIES AND APPLICATIONS FOR THE 5GHZ TO THE 100GHZ FREQUENCY DOMAIN FROM EUROPEAN POINT OF VIEW

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ABSTRACT

Wireless local networks and remote identification systems are emerging in the 5.2GHz to 5.8GHz Telecommunication link networks for inter-cell connections are to a high degree based on radio links in the frequency range between 13GHz and 60GHz. At 76GHz the first automotive radars are now available and in use. For these applications state of the art GaAs components are developed and provided by European sources. Up to X-band MESFETs are still carrying the load whereas else heterostructure transistors become dominant. This paper reviews the Activities from a European point of view.

INTRODUCTION

The rapidly growing demand for transmission of information continues to boost high frequency communication technologies with increasing frequency ranges. The convenience of being not fixed by a plug and a cable is the driving force for wireless mobile communication technology. For GaAs based components the market below 5GHz in 1998 represents roughly 80% of an overall market which is estimated to be around 900MioUS$. It is estimated that this dominance will continue for the next years. A detailed analysis of this market is given in various papers during this conference (see for reference /1/, /2/, /3/, /4/).

The market above 5GHz - up to 18GHz - was for a long period dominated by military systems for radar and electronic warfare. With the increasing demand for wide band radio links and the necessity to connect computers to high bit rate links under wireless conditions this market segment now is also dominated by commercial systems.

This paper will describe recent European developments for the civil use of GaAs components in the higher frequency range. The defense applications are covered in several other contributions to this conference.

MARKETS AND APPLICATIONS

The following table shows the major systems using GaAs components above 5GHz and their development status. Except for the automotive cruise control system all applications are for communication purposes. The market started for commercial applications (commercial radio links) and expands into consumer products (multi media terminal, video on demand converter,...).

Table 1 also reveals that today in Europe digital applications present a very small market share and are related to optical communication systems only.

Application	Frequency	Components	Status	Remarks
WLAN	5.2GHz	T/R MMICs	emerging '98	data com
Short distance communication	5.8GHz	Transceiver MMICs	emerging	large market for multi media and remote identification
DBS	10.5 - 11.5GHz	LNC MMICs and discrete HEMTs	existing	lowest cost, large quantity
Point to Point and Point to Multipoint	13 - 60GHz	T/R MMICs	PTP: started in '96 PTMP: starting in '98	commercial; very strong growth rate
Video Distribution Systems LMDS MVDS	28GHz 42GHz	first step: LNCs second step: Transceiver MMICs	LMDS: starting in '97 MVDS: starting in 2000 expected	consumer market, lowest cost
Optical links	up to 60GHz	digital drivers, MUX/DMUX, .. recovery, analog receivers	existing	today limited to commercial systems.
Constellation Satellite Com. Skybridge, Teledesic Skystation	Ku-band Ka-band Ka/Q-band	T/R MMICs for on board and for ground terminals	in preparation	driven by multi-media, aiming at commercial and consumer markets
Automotive Cruise Control	76GHz	Transceiver MMICs	first products on the road in '98	market evolving in significant quantities after 2004

Table 1: Systems relying on key components from GaAs

TECHNOLOGIES

In Europe several companies have established a sound GaAs technology for the open market, such as Siemens, United Monolithic Semiconductors (UMS, merger of former Thomson and Daimler-Benz activities), Philips(PML) and GEC/GMMT. Furtheron Alenia and Alcatel-Telettra have GaAs technology mainly for in-house use.

Power

For applications in WLANs and short distance communication mature MESFET technologies are available, offering multi-level metallization, E-/D-mode FETs and power options /5/.

This type of technology will continue to supply the volume of the lower frequency components up to about 10GHz and has proven to be fairly competitive versus advanced Silicon technology.
With increasing importance of power aspects, such as power added efficiency (PAE) and operation down the very low supply voltages, a new generation of low cost and high performance pseudomorphic HEMT technology is emerging. This technology aims at threshold voltage values close to zero volts, eliminating the necessity of a negative supply voltage and enabling a further increase of PAE beyond the 60% range.

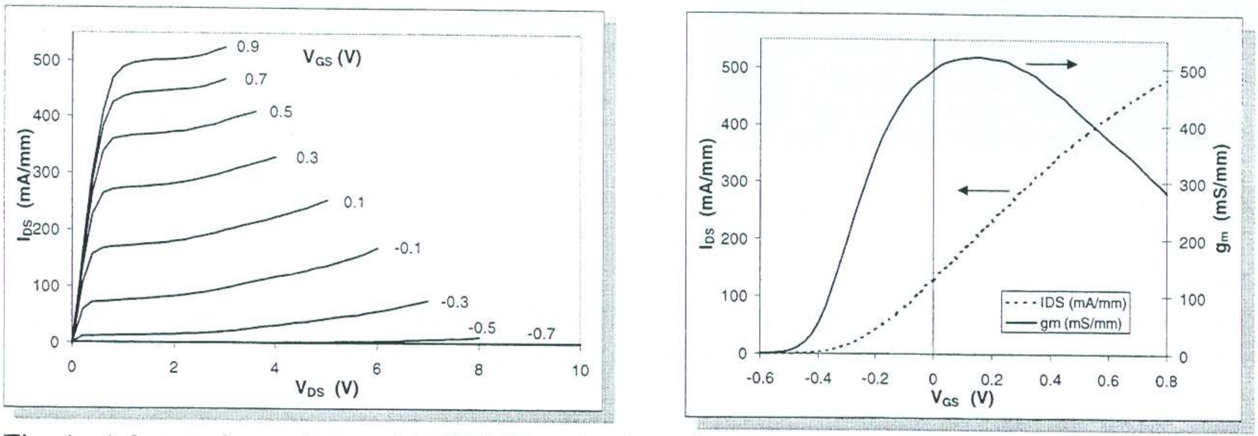

Fig. 1: Advanced pseudomorphic HEMT technology for power application up to the 12 GHz range (UMS)

Typical values are:

L_G	=	0.5um	V_{BDS}	>	11V
I_{DSmax}	=	420mA/mm (@ V_{DS} = 2.5V, V_{GS} = +0.6V)	V_T	>	-0.5V
g_{mmax}	=	500mS/mm	f_T	>	45GHz
			f_{max}	>	100GHz

For radio links and for satellite communication the required output power strongly increases with the emerging use of advanced modulation schemes (QPSK, 64QAM, ...)/6/. Up the 25dBm range the power requirements in Ku- and Ka-band can be fulfilled with standard HEMT technologies, used for low noise. For higher power a real power HEMT technology had to be installed. It typically features double side doping and double recess structures, leading to breakdown voltages up to 15 - 20V.
With increasing breakdown voltage the frequency limits (f_T) are shrinking leading to about 60GHz for 12V and to 40GHz for 20V V_{BDS} for a 0.25um device. Therefore for power amplifiers at 40GHz and 60GHz a further reduction of gate length is required.

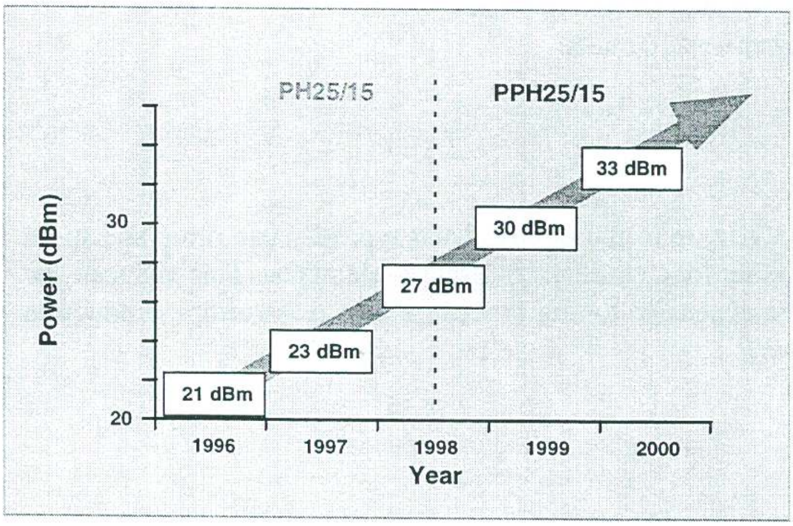

Fig.2: Development of output power versus time for HPAs inKa-band communication systems

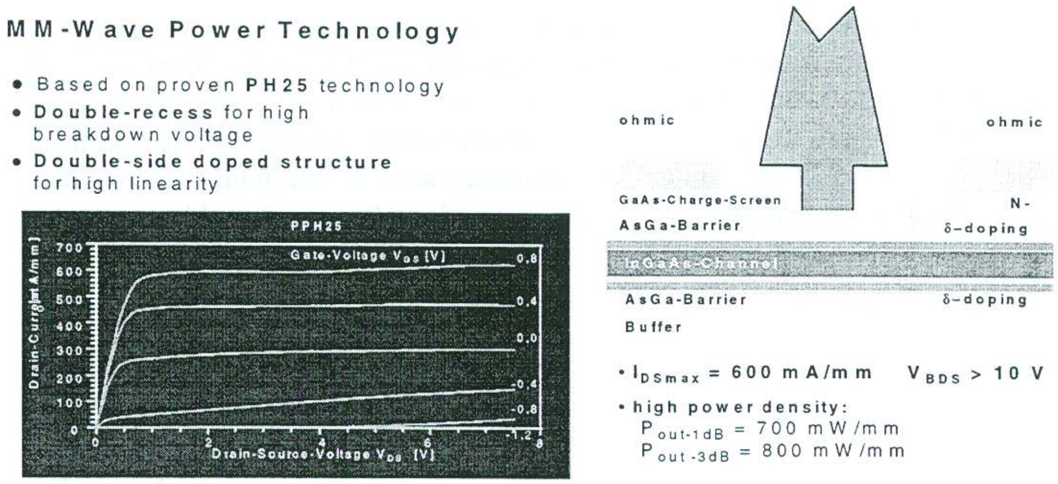

Fig.3: Power HEMT technology for Ka-band amplifiers.

Low noise

This is the original domain of HEMT devices and therefore well developed. Several companies provide good devices with performance close to the values given in table 2.

		PH25	PH15
gate length	Lg	0.25µm	0.15µm
max. transconductance	Gm	500 mS/mm	650 mS/mm
max. current	Idss	300 mA/mm	300 mA/mm
breakdown voltage	BVds	5.5 V	5.5 V
transition frequency	Ft	80 GHz	> 100 GHz
noise figure/associated gain	Fmin / Gass	1.5/8 dB @ 40GHz	2.0/6 dB @ 60GHz
power density	Psat	0.25W/mm	0.3W/mm

Table 2: Main features of pseudomorphic HEMT devices for very low noise and mm-wave circuits.

COMPONENTS

Today's **radio link systems** for the 13GHz up to the 60GHz band typically use more and more MMICs to replace the earlier hybrid solutions employing discrete elements. This reduces the assembly cost and nearly eliminates the expensive tuning procedure. For real volume production the MMIC solution is the only viable way.

The key functions to be supplied are:

- low noise amplifier
- downconverter
- upconverter
- driver- and transmitter amplifiers (with gain control elements)
- oscillator with tuning element, buffer amplifier and power divider.

These components have to be available for all respective frequency bands with power levels up to 30dBm at Ka-band /10, 11/.

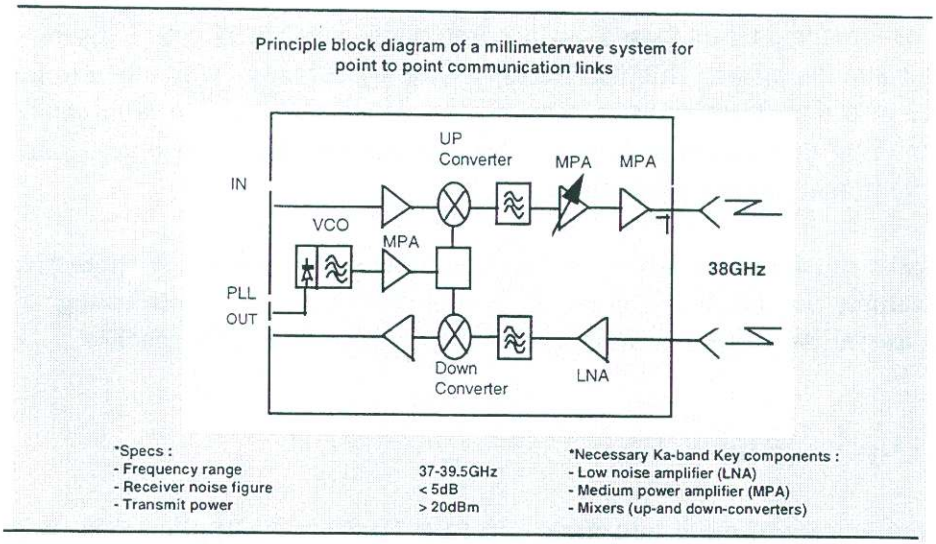

Fig.4: Typical functional block diagram for a radio link outdoor unit (example here for 38GHz)

For the emerging **MVDS systems** the typical block diagram is shown in Fig. 5. The configuration is design for the presently performed field tests to demonstrate the feasibility. For the final volume production further simplification and a higher degree of integration will follow /7/.

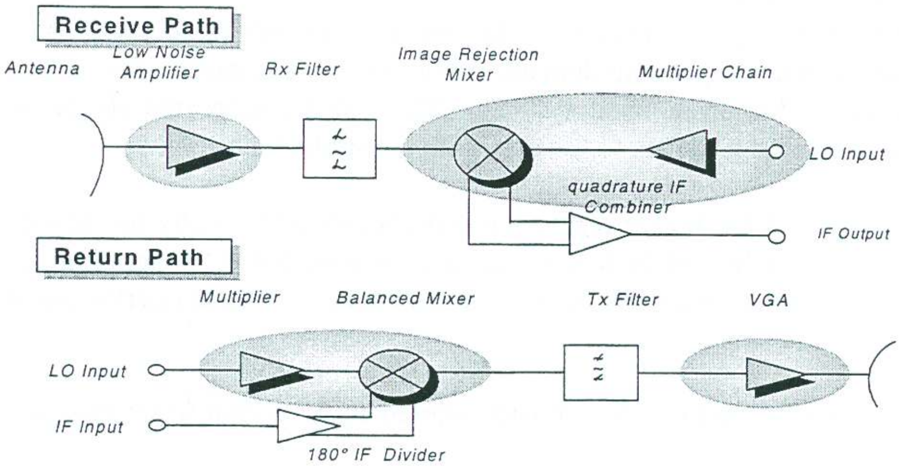

Fig.5: Millimeterwave frontend of MVDS test system. All active functions are available as GaAs MMICs /7/.

Automotive Cruise Control

This market today present the "high-end" of the mm-wave products. To be successful it also has to follow the price digression curve for consumer products. Target price for the complete MMIC RF-frontend is well below 50US$, even aiming below 20US$ for the complete chip set for quantities of several millions per year.

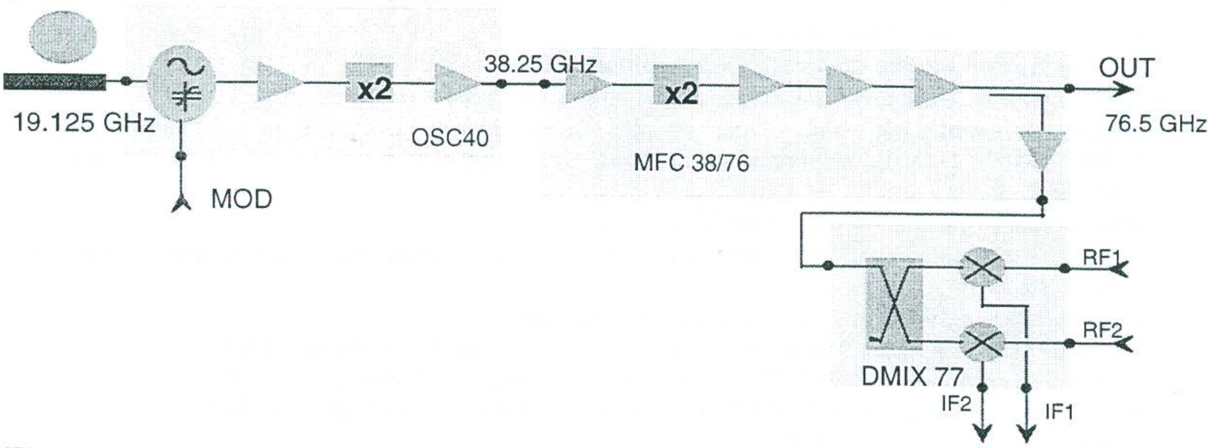

Fig. 6: Generic Production Chipset for Automotive Cruise Control System /8/

Today's first system will be on the market based on a combination of MMICs and discrete components for the oscillator and the mixer. This was necessary for a technology which had to be frozen several years before. In the meantime systems have been developed that are completely based on GaAs MMICs, entering production next year. Only so are the challenging price and lifetime objectives achievable in real volume production.

In the field of millimeterwave development strong research activities are supporting industrial developments. A good example is the work done at Fraunhofer IAF /9/, contributing to semiconductor components as well as the new design concepts and measurement approaches.

FUTURE EVOLUTION AND TRENDS

Mobile computing and communication, more and more linked to multimedia applications, will continue to be the driving force for the development of broad band wireless communication systems. In the frequency range up to about 10GHz circuits based on MESFETs will supply the major volumes, being in continuous competition to advanced Silicon components. Due to the increase in production volume GaAs will be competitive not only based on its inherently advantageous performance but also costwise.
For the higher frequency range the today's commercial radio link systems will rapidly become a consumer like technology, based on the expanding demand for broadband communication access (like broad band Internet access, video on demand systems). This will be supported by the an easily available satellite communication interface to the emerging constellation satellites.

The today's commercial price level of the higher frequency components will rapidly be reduced with increasing volume. This can be achieved by lower cost technologies, higher integration and improved yields due to more tolerance in the performance data, based on increased performance technology.

The high frequency GaAs component business has already started to be a significant business opportunity.

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